Appendix A: The Strengths, Weaknesses, Opportunities, and Threats (SWOT) analysis of all 9 SES frameworks undertaken in the study.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Framework** | **Strengths** | **Weaknesses** | **Opportunities** | **Threats** |
| **Ecocycle Framework (EF)** | * Comprehensive tool that helps organisations understand the flow of resources. * The assumption of decline can allow management actors to effectively map the system and improve the existing capacity of variety within the system (Holling, 1994). * It can be used to identify opportunities for resource conservation, waste reduction, and sustainable business practices (Nacher, et al., 2021). * It can be applied to a wide range of industries and sectors, including marine management (Gunderson & Holling, 2002). * The ability to consider scales of application is the predominant strength within this approach, the use of Panarchy addresses where different scales and disciplines intersect and how change on the different scales can occur and be orchestrated by management (Gunderson & Holling, 2002). | * There is a paradox in the success of operations that reduce the ability to change and stay adaptable in its wider environment (Holling, 1994). * Barriers are present in operationalising as actors within a system will face create barriers to consistent management actions and may be difficult for actors to comply with. The Ecocycle framework can be complex and will require specialised knowledge and skills to be used effectively (Rocha, et al., 2022). * The lack of direction to include stakeholders in the SES is indicative of this weakness (Nacher, et al., 2021). | * The ability to engineer variety strategically may provide resilient structures in facing new external problems facing the system (Rocha, et al., 2022). * The Ecocycle framework can help organisations improve their commitment to environmental sustainability and meet regulatory requirements related to marine management (Hurst & Zimmerman, 1994). * It can provide a structured approach for identifying and addressing environmental impacts in the marine environment through examining various levels of governance and problem focus. * It can support interdisciplinary research and collaboration between the natural and social sciences (von Wehrden et al., 2018). * It can help to inform policies and decision-making at local, national, and global levels (Seddon et al., 2016). | * The paradox in that the success of operations that reduces the ability to change and stay adaptable in its wider environment, and against exogenic pressures (Hurst & Zimmerman, 1994). * The Ecocycle framework may not be suitable for all types of operations or industries and may not provide a complete picture of the environmental impacts of an organisation's activities due to the complex nature of the analysis and differing environments. * It may face resistance from stakeholders who have vested interests in maintaining the status quo or who may see the framework as a threat to their interests (Schlüter et al., 2019). * The impacts of climate change on marine ecosystems could offer additional unforeseen impacts that the framework may not be equipped to tackle. |
| **Ecosystem Services Framework (ESF)** | * The ESF recognises the interconnectedness and complexity of ecological systems and the multiple functions and values of ecosystems (Evans, 2019). * It provides a holistic and integrated approach to environmental management and conservation by involving stakeholders in decision-making and supporting the integration of economic, social, and environmental considerations. * It can support interdisciplinary research and collaboration between the natural and social sciences (von Wehrden et al., 2018). * Possess the capacity to help inform policies and decision-making at local, national, and global levels (Seddon et al., 2016). * The ESF described by Turner and Daily (2007) recognises that the maintenance of biodiversity is both final ecosystem goods and benefit and an intermediate service since biodiversity is a major component of ecosystem structure, processes and services and benefits outcomes (Turner & Daily, 2007). Aligning with the EBM goals and criteria in biodiversity conservation and reversing biodiversity decline. | * The ESF is a broad and abstract concept, which can make it difficult to apply in practice. Previous work claims the ambiguous language of the ESF highlight the need for greater methodological and terminological consistency within the approach (Bull et al., 2016). * It may not always provide clear guidance on how to address specific environmental challenges and may require additional frameworks or tools to support implementation (Weitzman, 2019). * The lack of a singular accepted approach to the ESF may hinder application in different areas to their understanding and opinion of how this is to be implemented (Weitzman, 2019). * It may face resistance from stakeholders who have vested interests in maintaining the status quo, or who may see the framework as a threat to their interests (Schlüter et al., 2014). This offers threats to the effectiveness of the framework and could include competing interests and priorities among stakeholders. | * The ESF can provide a valuable framework for addressing complex environmental challenges, such as climate change, biodiversity loss, and natural resource degradation (Turner & Schaafsma, 2015). * It can support interdisciplinary research and collaboration between the natural and social sciences through validation processes and education and communication processes within the ESF. * It can help to inform policies and decision-making at local, national, and global levels (Seddon et al., 2016). Alongside the potential to promote alignment with existing policies (Bull et al., 2016). | * It may be vulnerable to changing political and economic conditions, which could impact funding and support for research and implementation (Bull et al., 2016). * It may face challenges in achieving widespread adoption and implementation, due to the complexity and abstract nature of the framework; hence, standardisation issues threaten the implementation of the approach. * The impacts of climate change on marine ecosystems could offer additional unforeseen impacts that the framework may not be equipped to tackle. |
| **Integrated Ecosystem Assessment (IEA)** | * The framework is sufficiently comprehensive and takes into account a wide range of socio-ecological actors (Monaco et al., 2021). * The feedback loops in the framework imply an adaptive quality to the approach, which is desirable for the Simple SES. * It has the capacity to support interdisciplinary research and collaboration between the natural and social sciences (von Wehrden et al., 2018). * It can help to inform policies and decision-making at local, national, and global levels (Seddon et al., 2016). | * May be time-consuming and resource-intensive to conduct and also require expertise to analyse and synthesise complicated results (Szymkowiak & Kasperski, 2020). * There is also a need to better incorporate other sectors and agencies with mandates within coastal and marine ecosystems to achieve full EBM with an IEA (Dickey-Collas, 2014). * Information necessary for the approach to implementing better planning may be lacking (Woods, 2021). | * Can inform the development of effective and sustainable management strategies for the ecosystem to improve ecosystem health in larger systems (Woods, 2021). * The emphasis on the use of stakeholders can facilitate greater support for the uptake of meaningful solutions. * Can help to identify new research questions and areas for further study. Alongside providing a solid base of evidence and data set for analysis of cumulative effects (Dickey-Collas, 2014). | * There may be limited capacity or expertise available to effectively implement the IEA approach, which could hinder its effectiveness (Szymkowiak and Kasperski, 2020). |
| **Integrated Systems Analysis (ISA)** | * Considers multiple factors and their interactions, providing a holistic view of the marine environment through the DASPSI(W)R(M) underpinning framework, which addresses different aspects of the marine SES through a cause-consequence approach. * Can identify key drivers of change and understand their impacts on the ecosystem. * The inclusion of the ten-tenets encourages integration and holistic approaches between sectors and stakeholders (Elliott, 2013). * The acknowledgement of endogenic and exogenic pressures provides good context for informed decision-making for both preventative and mitigative measures. * The B-B relation will aid specific information collection for biodiversity conservation measures which aligns with the Marine SABRES goals. * The socio-economic subsystem aids relevant information on ecosystem goods and services to be considered. * Sub-section 8(d) encourages the empowerment of citizens to engage in conservation measures through horizontal integration of management (Elliott et al., 2020). * The framework uses consistent terminology throughout the identification and analysis of drivers, activities, pressures, state changes and impacts (on welfare) and the response measures. This consistent terminology will aid simplicity of application and upscaling in comparison of data between testing / countries /etc. * The DPSIR framework and its derivatives (including DAPSI(W)R(M)) is a valuable tool and an effective scoping approach that has been applied in numerous environmental contexts to connect the causes, effects, and management of change, because of its simplicity and transparency, Tawfik (2023) suggests many international institutions recommended its application because of this simplicity. | * This approach requires a large amount of available data and resources to be effective. Due to the systems approach of analysing different aspects of an SES, unless a substantial amount of data is readily available, the requirement of the minimum amount of data needed for the approach may still be vastly time consuming. * Some literature suggests bias is present towards anthropocentric views as the main point of focus in the framework and approach (Binder et al., 2013). However, in sub-system 3, ecological aspects are individually assessed, and management are looking to manage activities and not the environment, hence, an appropriate approach, as long as it does not entirely favour anthropocentric outcome biases resulting in ecosystem loss of function and delivery of goods and benefits to society. * The application of the framework requires different levels of communication across operational, governmental, and managerial systems so data that is fit-for-purpose is to be communicated accordingly. This added complexity can be a weakness in the framework’s application within a Simple SES framework because it adds a layer of various communication styles to different stakeholders. However, the ISA offers complementary concepts and actions to counteract this issue, such as integrating the ten-tenets (Elliott, 2013) and utilising the dissemination diamond to ensure understanding and reduce complications in communication (Elliott et al., 2020). | * Can inform policy decisions and guide the development of marine management plans (Seddon et al., 2016). * Can improve the resilience of marine ecosystems to environmental stressors and support the sustainable use of marine resources. * The frameworks feedback loops may provide opportunity for adaption and transferability between areas once upscaled. * The DAPSI(W)R(M) framework when upscaled, has the capacity to overlap and data sharing to support predictions and mitigate cumulative effects in the form of nested repetitions of the system mapping (Elliott et al., 2017). * Opportunities to incorporate local knowledge, indigenous practices and existing management methods into the management outcomes by incorporating the viewpoints of stakeholders. * When the DAPSI(W)R(M) is expanded to a larger scale, a linked set of nested DAPSI(W)R(M) have been conceptualised and this provides a starting point when considering upscaling of the framework. This capacity provides the opportunity for development to address different levelled actors/ geographical scope and jurisdiction. | * The ISA may not be fully accepted or implemented by all stakeholders and may be limited by the availability of data and resources when upscaled.   + In countries where there is poor data, this could limit the full quantitative application of the underpinning DAPSI(W)R(M) framework. Particularly in developing countries, there is a lack of historical data, capacity and skills, infrastructure, and financial resources to undertake the necessary data collection (Jorge-Romero et al., 2022). * This framework requires a lot of different actors to work efficiently and simultaneously alongside each other in a timely manner. This may present the threat of inconsistency of outcomes and goal achievement between different countries / areas. If these inconsistencies are vastly different, this will inhibit comparison and use of information from data collected.   + E.g., many legislative processes in different countries, may work at different rates, so sub-system 8(a) may alter the speed of applications depending on the area. |
| **Social-Ecological System Framework (SESF)** | * The SESF recognises the interconnectedness of human and natural systems and the importance of considering multiple scales and levels of organisation (Guimarães et al., 2019). * It provides a comprehensive approach to understanding the dynamics of social-ecological systems and the impacts of human actions on the environment (Hinkel et al., 2015). * It can help to identify opportunities for sustainable development and conservation and inform strategies for addressing environmental and social challenges (Partelow, 2018). * SESF provides a frame for developing different degrees of specificity in differentiating different tiers. | * The SESF is a complex and abstract concept, which can make it difficult to apply in practice (Partelow, 2018). * Applicable literature surrounding the SESF is heterogeneous. Hence, it is unclear how empirical data can be compared across systems in a meaningful way without substantial simplification and re-formatting of the data (Partelow, 2018). * It may not always provide clear guidance on how to address specific environmental or social challenges in implementation (Thiel et al., 2015). This framework is conceptually prescriptive, although offers no further guidance on application. Hence, its abstract nature is a barrier to the implementation of the SESF. * It may not adequately account for the political and cultural dimensions of human-environment interactions and may not adequately address issues of social justice and inequality (Thiel et al., 2015). * Studies have explored the validity of the SESFs claim to create a common language among actors within the SES. The findings, when conducting analytical comparison across cases, stated the majority of the studies did not define concepts or make ways of measuring them transparently. (Thiel et al., 2015). | * The SESF can provide a valuable lens for analysing and addressing a wide range of environmental and social issues, such as climate change and biodiversity loss. * It can support interdisciplinary research and collaboration between the natural and social sciences (von Wehrden et al., 2018). * It can help to inform policies and decision-making at local, national, and global levels (Seddon et al., 2016). | * The SESF may not be widely adopted or recognised by policymakers and other decision-makers, which could limit its implementation and usefulness. * It may face resistance from stakeholders who have vested interests in maintaining the status quo or who may see the framework as a threat to their interests (Schlüter et al., 2014). * It may be vulnerable to changing political and economic conditions, which could impact funding and support for research and implementation through the SESFs historical roots in institutions. |
| **Social Ecological Action-Situations Framework (SE-AS)** | * The SE-AS framework emphasises social-ecological interactions and how they give rise to emergent phenomena (Theil, 2015). * It introduces two additional types of action situations that provide a more comprehensive view of complex social-ecological systems and reduces bias to either of the social or environmental components (Herzog et al., 2022). * The framework has been applied to support the development of global biodiversity targets and identify mechanisms of policy change in fisheries co-management (Herzog et al., 2022). * It can support interdisciplinary research and collaboration between the natural and social sciences (von Wehrden et al., 2018). * Provides a helpful structure for understanding complex causal loop diagrams through the separation of components (Herzog et al., 2022). | * Demands a large amount of data to work sufficiently; hence in data-poor areas/low-funded areas, this may hinder the implementation. * The SE-AS framework is a relatively recent development, and as such, it may not yet have been extensively tested or applied in a wide range of situations (Herzog et al., 2022). However, the application to lakes by Herzog (2022), provides a foundation for improvement. * A lack of difference between crucial and non-crucial ASs for establishing an emergent phenomenon (Herzog et al., 2022) may hinder simplicity and consistency between systems. * It may be difficult to operationalise the framework in practice, as it involves identifying and analysing complex networks of interacting action situations (Herzog et al., 2022). * The framework may be too complicated for some users and may require specialised training or expertise to apply effectively (Herzog et al., 2022). * There is a reference to societal values; however, there is no direction for stakeholder inclusion. | * The SE-AS framework offers a unique approach to understanding and managing complex social-ecological systems. As more research is conducted using the framework, it may generate insights and strategies that can be applied in a range of contexts. * It can help to inform policies and decision-making at local, national, and global levels (Seddon et al., 2016). The framework may be particularly useful for addressing challenges relating to sustainable development, climate change, and environmental degradation. * The framework could potentially provide a communication tool outside academic bounds that illustrates the role of stakeholders and ecosystem elements in an SES while stimulating discussions on the underlying mechanisms of SES (Schlüter et al., 2019). | * The SE-AS framework may be perceived as being too complex or abstract, which could limit its adoption and use by practitioners and policymakers (Herzog et al., 2022). * It may be difficult to compete with more established frameworks or approaches that are already widely used in the fields of social-ecological systems and sustainable development. * It may face resistance from stakeholders who have vested interests in maintaining the status quo, or who may see the framework as a threat to their interests (Schlüter et al., 2019). * The impacts of climate change on marine ecosystems could offer additional unforeseen impacts that the framework may not be equipped to tackle; due to the lack of external variable considerations. |
| **Sustainable Livelihood Approach (SLA)** | * The sustainable livelihoods approach recognises the multiple factors that affect people's livelihoods and the importance of considering economic, social, political and some environmental factors. * It emphasises the need for an integrated and holistic approach to development and the importance of involving all stakeholders in decision-making (Knutsson, 2006). * It supports the diversification and improvement of people's livelihoods and the building of resilience to shocks and stresses. Alongside seeking to understand changing combinations of modes of livelihood in a dynamic and historical context. * Calls for investigation of the relationships between different activities that constitute livelihoods and draws attention to social relations and acknowledges the need to move beyond narrow sectoral perspectives and emphasises seeing the linkages between sectors (DFID, 2001). * Acknowledges ‘smaller voices’ in stakeholders (Serrat, 2017). * It can support interdisciplinary research and collaboration between the natural and social sciences (von Wehrden et al., 2018). * It can help to inform policies and decision-making at local, national, and global levels (Seddon et al., 2016). | * The sustainable livelihoods approach is a complex and abstract concept, which can make it difficult to apply in practice. As it does not provide clear guidance on how to address specific development challenges, it may require additional frameworks or tools to support implementation (Serrat, 2017). * It may not adequately account for the political and cultural dimensions of development and may not adequately address issues of social justice and inequality. Hence a substantial weakness is the lack of attention to inequalities of power (Serrat, 2017). * Underplays the fact that enhancing the livelihoods of one group can undermine those of another which can further undermine different assets (Serrat, 2017). * The lack of attention to the services ecological elements provide within the approach is likely to result in solely biased towards anthropogenic outcomes; the approach recognises Final Ecosystem Goods and Services (FEGS). However, it fails to acknowledge marine processes and functioning, which play a fundamental role in the production of ecosystem services. | * The sustainable livelihoods approach can provide a valuable framework for addressing poverty issues and vulnerability in developing countries. * It can support interdisciplinary research and collaboration between the natural and social sciences. * It can help to inform policies and decision-making at local, national, and global levels (Seddon et al., 2016). | * The sustainable livelihoods approach may not be widely adopted or recognised by policymakers and other decision-makers, which could limit its impact and usefulness. Particularly due to the main focus of the framework being poverty alleviation, hence the application to marine management will require a lot of alterations (Serrat, 2017). * As it is guided heavily by social systems, the threat of resistance from stakeholders who have vested interests in maintaining the status quo, or who may see the approach as a threat to their interests, is a potential threat to the use of the SLA. * It may be vulnerable to changing political and economic conditions, which could impact funding and support for research and implementation (Bull et al., 2016). |
| **The Systems Analysis Framework (SAF)** | * The framework focuses on the interconnections between varied factors in marine ecosystems and can provide a comprehensive view of marine systems (Støttrup et al., 2017). * The SAF provides tools alongside actions to guide users and transdisciplinary approaches are incorporated throughout to aid communication and inclusion (Støttrup et al., 2017).   + Including stakeholder involvement tools to enhance cooperation, inclusion, and incorporation of stakeholders to the process (Inácio & Umgiesser, 2019). Alongside recent works improving upon the use of stakeholders in collaborative decision-making (Gillgren et al., 2019). * The freedom the SAF provides in the system formulation step allows for flexible application to different testing areas. This may increase the applicability of the framework dependent on area-specific factors, such as funding or data type and presents adaptive features (McFadden et al., 2010). * It can support interdisciplinary research and collaboration between the natural and social sciences (von Wehrden et al., 2018). * It can help to inform policies and decision-making at local, national, and global levels (Seddon et al., 2016). | * The success of the framework is heavily reliant on data and information, which may not always be available or accurate. * Lack of supporting tools regarding stakeholder engagement and the development of indicators hinder the application of the SAF in practice as the comparability may differ substantially between areas (Hopkins et al., 2011). * Whilst some aspects promote simplicity of application (e.g., the prescriptive tools), the SAF has been criticised for the complex terminology used in the approach and for lacking guidance on the inclusion of all parties and surrounding the implementation and monitoring steps in the context of policy and decision making (Inácio & Umgiesser, 2019). * As an open methodological framework, a weakness of the approach is the requirement of experts to implement the steps. As, the most technical aspects of the methodology, such as stakeholder interaction and construction of the model and scenarios are not rigidly defined, a degree of interpretation is required to implement these elements, and without experts to aid implementation, the model may not work as effectively as designed (Tomlinson et al., 2011). | * The growing recognition of the importance of sustainable management of marine resources is amplified in the SAF approach. Further, the development of new technologies and tools for studying marine social-economic-ecological systems may advance alongside this. * By implementing this approach, the opportunity exists to improve the availability of data and information on marine ecosystems for future use. | * It may face resistance from stakeholders who have vested interests in maintaining the status quo, or who may see the framework as a threat to their interests (Schlüter et al., 2014). This threatens the effectiveness of the framework and competing interests and priorities among stakeholders could lead to lowest common denominator effects. * Political and economic pressures may pose threats to the implementation and upscaling of this framework. |
| **Vulnerability Framework (VF)** | * It can help to inform policies and decision-making at differing scales, including local, national, and global levels, in strengthening systems’ adaptive capacities (Seddon et al., 2016). * The framework presents adaptive and resilient features relating to vulnerability * It can support interdisciplinary research and collaboration between the natural and human systems (von Wehrden et al., 2018). | * A conceptual framework with no prescriptive method of application, so a lot of development would be necessary to align with the goals of Marine SABRES. * It may be difficult to quantify and measure the various components of the framework (e.g., exposure, sensitivity, adaptive capacity) in a precise and objective way; this will also hinder comparability between systems. * The outcome information relating to the vulnerability context may not provide achievable strategies for reducing risk due to the conceptual nature of the framework (Turner et al., 2003b). * Whilst the framework includes favourable features relating to resilience, other encompassing characteristics such as stakeholder inclusion and holism were not present. | * The various temporal and geographical scales could help with the prioritisation of interventions and issues. This could potentially provide opportunities at a policy level to support policy-making related to risk management and climate change adaptation in relation to vulnerable communities, such as coastal areas. | * The impacts of climate change on marine ecosystems could offer additional unforeseen impacts that the framework may not be equipped to tackle, for example, cumulative effects. * Lack of prescriptive methods may result in differing applications and reporting of the framework when used and further upscaled throughout Europe (Turner et al., 2003b). |